Use of Clustered Mark-Recapture Methods to Monitor Bottlenose Dolphins (*Tursiops truncatus*) in the Outer Banks, North Carolina

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ABSTRACT

Understanding population structure and monitoring demographic change is important for conserving populations. This study examined the dynamics of a seasonally-occurring bottlenose dolphin population in Roanoke Sound, North Carolina. From 2008-2013, 141 photo-identification surveys were conducted from which 413 distinctive dolphins were identified. Bayesian mark-recapture modeling was used to identify population clusters based on similarities in capture/identification probabilities. Dolphins were assigned with maximum probability to three distinct clusters, and most (407/413) of these individuals could be assigned to a specific cluster with high probability, with 346, 29 and 31 dolphins having the majority of their allocation density (>50%) associating them with clusters 1, 2 and 3 respectively. Clusters differed in average annual identification probabilities (C3, p=0.91; C2, p=0.60; C1, p=0.15), and dolphins assigned to C3 were identified on more days (median=19 days, range=3-31), compared with C2 (median=6, range=1-12) and C1 (median=1, range=1-4). Abundance estimates differed by cluster (C1, N1=501, 95% HDPI=390-641; C2, N2=31, 95% HDPI=18-51; C3, N3 = 28, 95% HDPI=23-34). To test model fit, we used Bayesian posterior predications and found a plausible fit for only C2 (p-values = 0.35, 0.75) and C3 (p-values = 0.45, 0.40). For C2, average annual number of "deaths" slightly exceeded recruits (D2=5, 95% HDPI = 0-15; R2=3, 95% HDPI = 0-11), inferring abundance decline. For C3, deaths and recruitment were balanced (D3=2, 95% HDPI = 0-5; R3=2, 95% HDPI = 1-4), inferring a stable population. We found a high degree of transient site fidelity (C1) in addition to a small number of residents (C2 and C3) in Roanoke Sound. C3's high identification probability enabled monitoring its real population dynamics that were not confounded by catchability problems, as in the case of C1. This study demonstrates the importance of describing population structure and monitoring changes over time so that appropriate conservation measures can be implemented.

INTRODUCTION

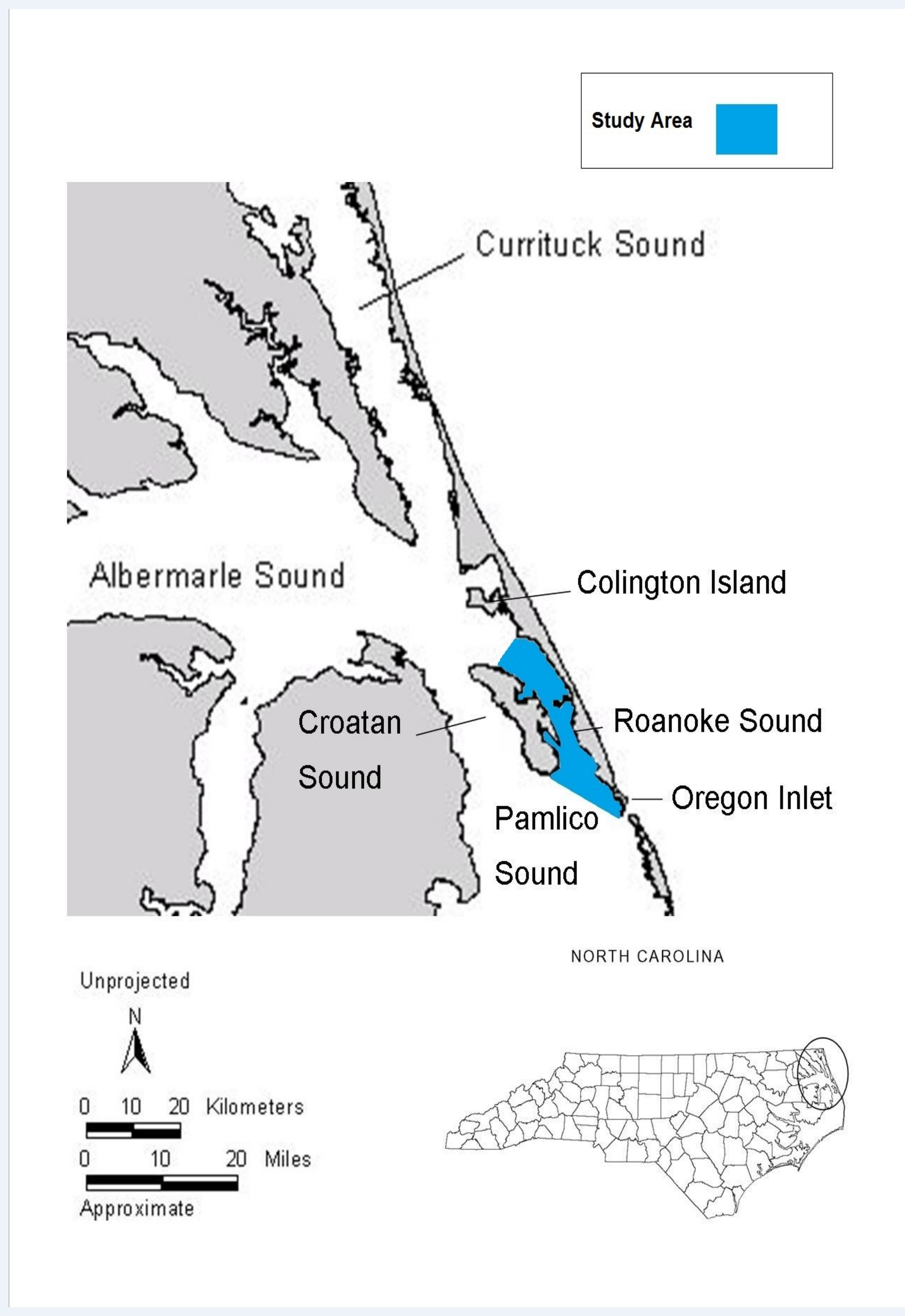
- Examining demographic trends within a population is important for understanding its viability over time (Fearnbach et al. 2012).
- Photo-identification is a useful mark-recapture technique monitoring bottlenose dolphin populations over time (Hammond 1990; Wilson et al. 1999).
- Bottlenose dolphins (*Tursiops truncatus*) occurring in Roanoke Sound, NC belong to the Northern North Carolina Estuarine System Stock (NNCESS), ranging from southern VA to Beaufort, NC (Waring et al. 2015). Long-term seasonal exchange has been documented between Roanoke Sound and Beaufort, NC area (Fuentes and Taylor, 2016; Mason and Taylor, 2016).
- Insight into the population dynamics of bottlenose dolphins in Roanoke Sound is useful to further understanding the sustainability of the NNCES stock and how individuals use this area.

OBJECTIVES

1)Use photo-identification to monitor individuals dolphins annually in Roanoke Sound, NC.
2)Adapt a Bayesian mark-recapture model to identify population clusters based upon individual capture probabilities.
3)Estimate abundance and monitor demographic trends for each cluster.

STUDY AREA

Figure 1: Roanoke Sound Study Area



- Study area spanned Roanoke Sound, approximately 41 miles² from northern tip of Roanoke Island south to Oregon Inlet (Figure 1).
- Limited exploratory surveys covered the Albemarle, Currituck, Croatan, and Pamlico Sounds.

METHODS

- Conducted dedicated and opportunistic field surveys from 2008–2013. Sampling period ranged from April—November.
- Employed standard photo-identification techniques for photographing dorsal fins (Würsig and Würsig 1977).
- Used FinBase (Adams et al. 2006) for processing sighting data and dorsal fin images. Excluded poor quality and low/not distinct fins from analysis.
- Applied Bayesian mark-recapture approach (Durban et al. 2010) to identify clusters with different levels and patterns of capture probability over time (Gardner et al. 2010; Fearnbach et al. 2012). Modified approach to increase ability to resolve distinct clusters:
  1. Used counts of number of days each dolphin was identified each year instead of binary presence/absence per year
  2. Estimated demographic parameters from independent probability model for each cluster
- Used WinBugs software (Lunn et al. 2000) to implement Markov Chain Monte Carlo (MCMC) sampling (30,000 MCMC iterations) to estimate posterior distributions for each parameter. Augmented the data with up to 1500 possible unobserved individuals.
- Used Bayesian posterior predictions to test model fit. Posterior predictive p-value close to 0.5 indicated good model fit (Gelman et al. 1996).
- Abundance estimates accounted for proportion of animals with both marked and unmarked fins.

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RESULTS

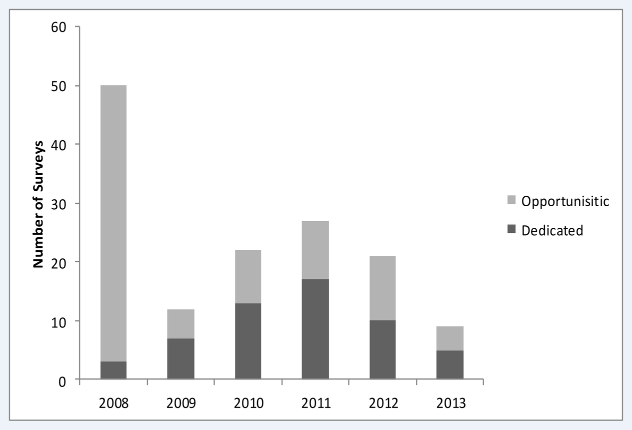

Figure 2: Field Survey Effort

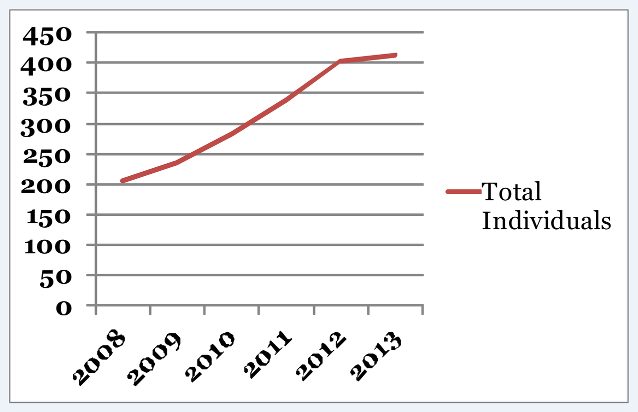

Figure 3: Discovery Curve

- We conducted a total of 141 surveys from 2008-2013. Survey effort and type varied by year (Figure 2).
- A discovery curve showed a continuous increase in new individuals throughout the study period (Figure 3).
- 413 distinctive dolphins were identified from high quality photographs. Twelve dolphins were seen in all 6 years.

Cluster	Probability of Identification (p)	Median number/ range of days seen	Average Survival (mu.phi)	Average Annual Abundance (N)
1 ("transients")	0.15 (0.09-0.22)	1 day (1-4)	-	501 (390-641)
2 ("residents")	0.60 (0.41-0.78)	6 days (1-12)	0.76 (0.15-0.93)	31 (18-51)
3 ("residents")	0.91 (0.85-0.95)	19 days (3-31)	0.82 (0.14-0.97)	28 (23-34)

Table 1: Parameter estimates for clusters (95% highest probability density intervals (HPDI) are shown in parentheses)

- Up to 6 different clusters sampled during MCMC iteration draws from model. Dolphins assigned with maximum probability to 3 distinct clusters; majority of individuals (407/413) assigned to specific cluster with high probability (p>0.5).
- Cluster 3 individuals had very high average annual identification probability (p=0.91) (Table 1).
- Dolphins assigned with high probability to Cluster 3 were sighted on more days compared to Clusters 1 and 2 (Table 1).
- Average annual abundance estimates (N) varied by cluster, with most unseen individuals assigned to Cluster 1 (Table 1).
- Approximately 1107 individuals (N_{super}=1092; 95%HPDI 940-1527) were alive and used the study area during the study period.

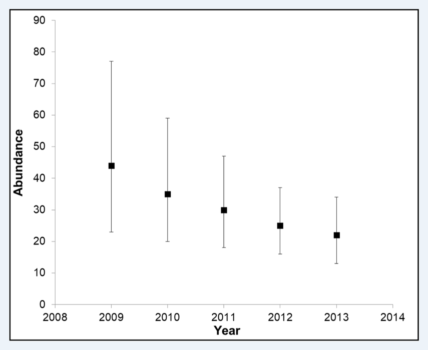

Figure 4a: Average annual Cluster 2 abundance (N_2) (2.5% and 97.5% HPDI shown with vertical lines)

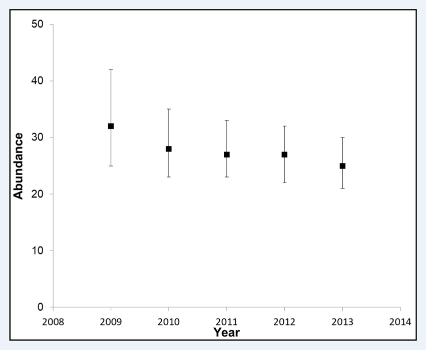

Figure 4b: Average annual Cluster 3 abundance (N_3) (2.5% and 97.5% HPDI shown with vertical lines)

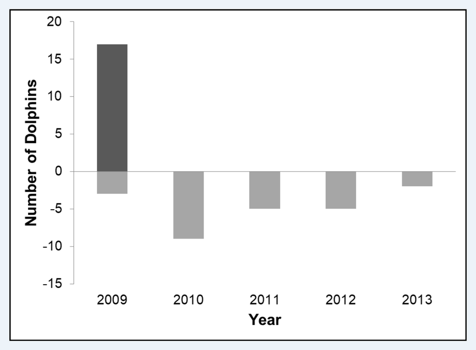

Figure 5a: Annual apparent mortality (D_2) and recruitment (R_2) estimates for Cluster 2

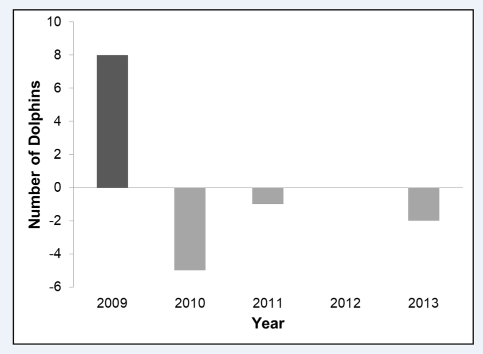

Figure 5b: Annual apparent mortality (D_3) and recruitment (R_3) estimates for Cluster 3

- Assessment of demographic trends focused on Cluster 2 (pvalue.count=0.35, pvalue.p0=0.75) and Cluster 3 (pvalue.count=0.45, pvalue.po=0.40) due to posterior predictive p-values indicating good model fit for only these two clusters.
- Clusters 2 and 3 both had relatively high survival probability (mu.phi) (Table 1).
- For Cluster 2, annual apparent mortality slightly exceeded number of recruits, resulting in an inferred abundance decline (Figure 5a). However, this was likely due to a large number of dolphins seen in the first study year and not seen again (Figure 4a), and this may represent "apparent death" of dolphins that have not been observed visiting the study area in recent years with lower search effort.
- For Cluster 3, annual apparent mortality and recruitment were balanced, inferring a stable population (Figure 5b). Average annual abundance appeared consistent across years (Figure 4b).

DISCUSSION

- Small resident (Clusters 2, 3) and larger transient (Cluster 1) clusters were identified within the Roanoke Sound population.
- Modifications to the Bayesian mark-recapture model allowed further detection of heterogeneous sighting frequencies.
- Higher identification probabilities of Clusters 2 and 3 enabled monitoring of real population dynamics that were not confounded by problems of low catchability as found for Cluster 1.
- Future studies will focus on incorporating 2014 data into the assessment to examine the effects of the 2013 morbillivirus epidemic that affected the NNCES stock.

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